LAKE ONTARIO CLADOPHORA STUDIES
IJC SURVEILLANCE PROGRAM 1981

Prepared for

ONTARIO MINISTRY OF THE ENVIRONMENT

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President.

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Limnos Ltd.

SUMMARY AND CONCLUSIONS

(1) One location in Lake Ontario at Oakville was sampled to quantitate Cladophora biomass and provide chemical analyses of the plant and water quality. A total of fifteen series of algae samples was collected by diver and reported on.

(2) Sampling and analytical procedures were according to standard IJC practice and comparable to the 1979 and 1980 Lake Erie Cladophora monitoring program.

(3) Cladophora was found to commence growing in Lake Ontario at the end of May. The maximum biomass occurred about July 1 when the crop released and was largely washed ashore. Some regrowth and sloughing occurred during the summer. No fall crops developed.

(4) All phosphorus and nitrogen measurements in water samples from Lake Ontario were higher than Lake Erie with ammonia and soluble phosphorus exceeding Lake Erie levels by a factor of three.

(5) The maximum biomass was found to occur at the 1.5m depth where a maximum of 192 gm./m^2 D. W. was measured in June. Maximum standing crop at 3m and 5m was significantly less than in shallower water being 81 and 46 gm./m^2, respectively.

(6) Tissue analysis as a percentage of dry weight (D. W.) indicated ash levels to vary from 18 to 73% (mean 48.8%), total nitrogen 1.1 to 4.8% (mean 2.87%) and phosphorus 0.08 to 0.7% (mean 0.23%).

(7) A comparison with data collected at the same site in 1972 indicated the same level of Cladophora standing crop in mid-July, but a lower tissue phosphorus content.

(8) A comparison with Lake Erie (Eastern Basin) data collected in 1979 and 1980 indicated a lower peak standing crop in Lake Ontario at 1 to 1.5m, but this may have been due to a sudden and early release. Tissue phosphorus levels were significantly higher in Lake Ontario.

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(9) A trend to lower tissue phosphorus analysis and higher N:P ratios since 1972 suggests a reduction in available phosporus in Lake Ontario which has not yet reached limiting concentrations.

(10) Attempts to measure Cladophora production using natural bed rock substrates were not successful due to logistic problems.

(11) An experiment to determine the potential of a fathometer for determining Cladophora distribution indicated that it did not differentiate growth from bottom features.

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LAKE ONTARIO CLADOPHORA STUDIES

INTRODUCTION

In 1981, a program was established by the Ontario Ministry of the Environment to determine the current status of Cladophora growth in Lake Ontario. The algae Cladophora grows in quantity along the open rocky shores of Lake Ontario. Since at least 1958 (MOE 1973), it has been a problem to shoreline recreational uses, commercial fishing and municipal and industrial water treatment plants. Its growth, where environmental requirements are suitable, is believed to be dependent on sufficient phosphorus resources and that its abundance may vary with the availability of this fertilizing element (Neil and Owen, 1964, Limnos, 1981).

In 1979, a program was established by the Lake Erie Surveillance Committee of the International Joint Commission with the following objectives:

1. To monitor the growth rate, density and distribution of Cladophora.

2. To determine the relationship(s) between environmental conditions and Cladophora growth.

3. To establish a systematic data base formulated from the results of the Lake Erie Cladophora monitoring.

A study at Rathfon Pt., Lake Erie was conducted during the summers of 1979 and 80 to address these objectives and a report of findings issued. (Limnos, 1981)

In 1981, an IJC surveillance program was established for Lake Ontario and the decision was made to include a study having the same general objectives for Lake Ontario. A contract to undertake the field and reporting responsibilities was established with Limnos Ltd. and

the following report is our summary of findings.

BACKGROUND INFORMATION

Two significant studies have been made of Cladophora in Lake Ontario prior to the present investigation. The first was work done in the period between 1958 and 1962 by the Ontario Water Resources Commission and the second by Owen in 1972 under the aegis of the International Field Year for the Great Lakes program.

The early studies developed when Cladophora became a major problem along the shoreline of Lake Ontario, particularly in the area between Toronto and Hamilton. Studies were principally directed to the cause for an apparent increase in growth and practical solutions that might resolve the problem. Water quality surveys to establish baseline nutrient levels were conducted over several years and observations providing qualitative information on algal abundance were reported. The principal thrust was directed to the evaluation of algicides both in the laboratory and the field, and subsequently lake testing in both L. Ontario and L. Erie was undertaken. The results demonstrated that control could be achieved with identified algicides, but funds to conduct large-scale control programs were not available. There was a general reduction in the severity of the problem during this period, and while problems continued to occur, people have learned to live with the inconvenience and water-taking facilities have been engineered to deal with problems previously encountered.

In 1972, the IFYGL program was launched with the objective of coordinating a major international effort to establish an indepth record

of the physical, chemical and biological conditions in L. Ontario. As one component of this study, an evaluation of Cladophora growth in the lake was conducted by MOE in Canadian waters and EPA in the United States waters. The study was to include a quantitative assessment of Cladophora biomass taken once during June, July and August at designated locations and the analysis of subsamples for tissue nutrient concentration.

The Ministry of the Environment responsibilities were largely completed with seven stations sampled, one to three times during the summer generally at 1.5m, 3.0m and 5.0m. Analyses were made for tissue phosphorus and nitrogen concentrations. On the U. S. shore, an essentially complete set of records exists for five stations at the same depth for each of the three months. Ash levels were determined but to the best of our knowledge, no tissue nutrient analyses were conducted.

No organized report of these findings is available, but a summary was prepared (Limnos, 1974) for the IJC Research Advisory Committee. (Appendix ii). This is the first quantitative information available on Cladophora in L. Ontario.

In the development of the current study, it was decided that the same Oakville station would be used so that comparative information to the 1972 survey would be obtained but that a more comprehensive weekly sampling program would be established. A second objective was to develop a procedure for measuring production based on repeated collections from identified natural substrate locations. (See Figure 1)

A number of attempts have been made to determine the distribution of Cladophora in L. Ontario. Procedures used have included qualitative

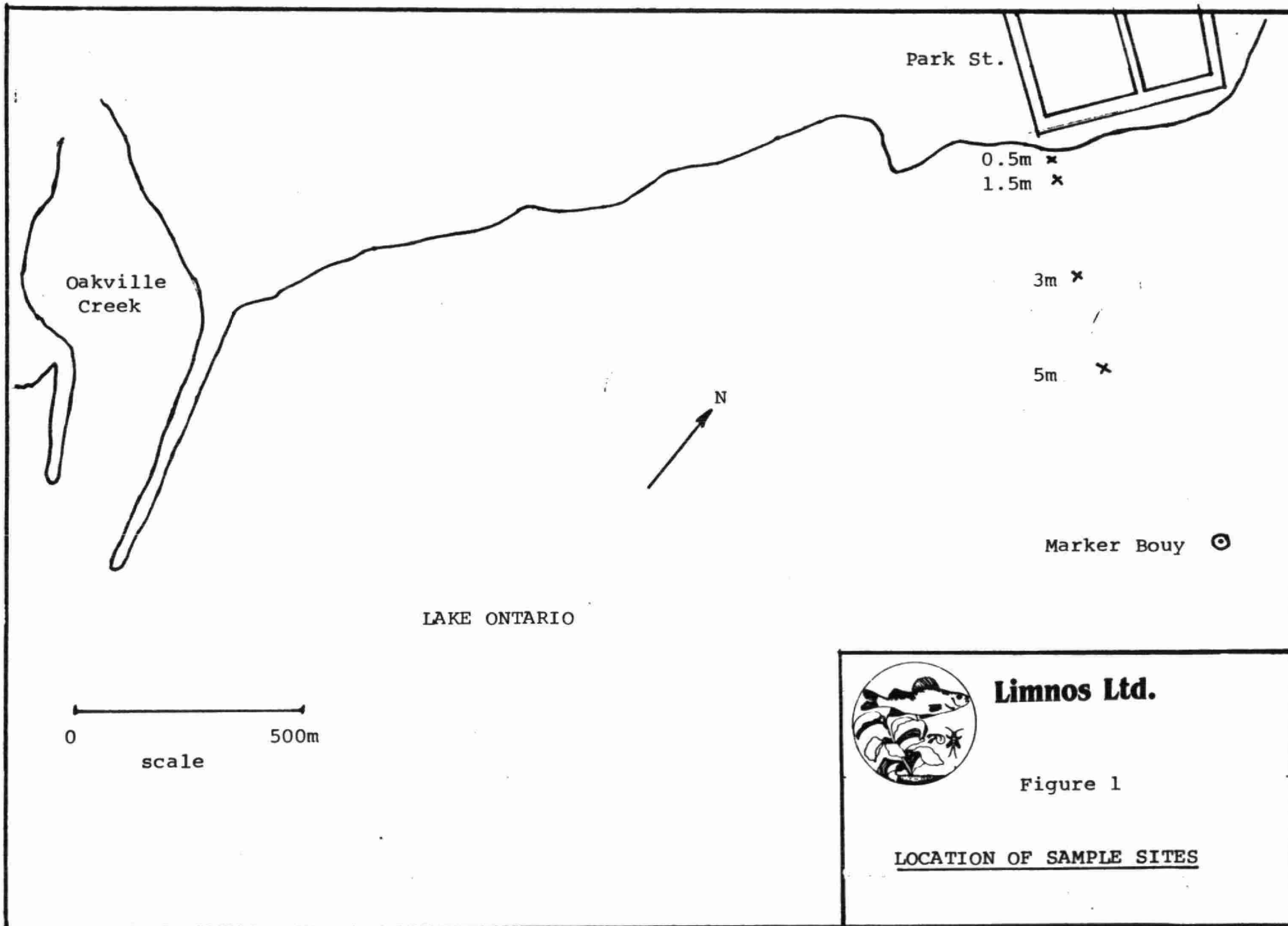


Figure 1

LOCATION OF SAMPLE SITES

mapping of shoreline accumulation (Limnos, 1974) and remote sensing techniques using a multispectral sensor system and data processing analyses (Wezernak et al, 1974). While the remote sensing evaluation was generally satisfactory, perfect water conditions, associated ground truth data and a high cost have limited general use of this procedure. It appeared possible that a precision echo sounder might have sufficient resolution to identify growth of Cladophora on firm substrates and an addendum to this contract was provided to assess the potential of this technique.

METHODS

Sampling and analytical procedures for Cladophora monitoring under the IJC surveillance program were established for the 1979 season on L. Erie and described, "Special Report #22, Field and Laboratory Methods, Milner and Carney, 1980 - Gt. Lakes Laboratory, Buffalo". As participants in the Canadian section study, these procedures were adopted for L. Erie and used for the 1981 L. Ontario program.

Algae sampling in Lake Ontario was conducted at four depths, 0.5, 1.5, 3.0 and 5.0m. The depths were selected to conform with sampling conducted by Owen in 1972 so that direct comparisons of results could be made. Sampling frequency was intended to be weekly from the commencement of growth to mid-October.

The collection of algae samples followed the general procedures described in the Limnos report to MOE, Lake Erie Cladophora Studies 1979-80. Biomass was collected by diver using the pump suction sampler described in the above report. In practice, all biomass samples were

taken by removing all available growth from three separate 0.25m quadrats. Each quadrat sample was squeezed to remove surplus water, labeled, bagged separately and kept chilled until analysed. This process was repeated at each of the four sampling depths.

Samples for production were intended to harvest growth from a previously selected area at each depth which had been cropped and re-sampled on a weekly, bi-weekly and monthly basis. For a variety of reasons, difficulties were encountered with the logistics of a continuing series of production sampling and questionable data resulted. (See discussion).

Four water samples for chemical analysis were collected each sampling day. These included a sample taken 1m below the surface collected well offshore and beyond the 5m site to obtain water believed to be representative of the open lake and unaffected by thermal bar or shoreline nutrient flow. Samples at 1.0 and 4.0m at the 5m sampling site and one sample at the shoreline collected at 0.5m were taken to document water quality within the growth areas. General water quality parameters including NH_3, NO_3, total Kjeldahl, total Phosphorus, dissolved reactive Phosphorus and conductivity were measured at the MOE Rexdale Laboratory. Samples were iced in warm weather and delivered the same day.

Physical measurements including air temperature, the water temperature of each water sample and secchi disc readings were recorded. To measure light attenuation, simultaneous secchi disc readings and micro-einstein units were measured on two occasions representing a range from heavy cloud cover to bright sunlight.

Analyses of water samples were conducted by the MOE laboratory according to described analytical procedures. Algae samples returned to the laboratory at York University were first examined and visible debris and organisms removed. Surface water was absorbed with paper toweling until no further moisture was removed and each sample weighed. Dry weights were obtained by holding samples in a constant temperature oven at 64^{o}C until no change in weight occurred. Cladophora volume was determined by measuring the volume of each cleaned and blotted dry sample in a graduated cylinder.

A record of algae growth and shoreline accumulations was kept by a photographic record. Pictures could only be taken underwater when water clarity permitted. A list of locations and dates is appended (Appendix iii) and copies of the photographic slides provided as a separate submission.

RESULTS

A total of seventeen sets of chemical and environmental data were obtained and fourteen sets of algae samples.

Environmental Data

A summary of environmental measurements made on each sampling date is provided in Table I. Water temperatures were approximately 9^{o}C when the first samples were taken in May and increased to 18^{o}-20^{o}C in mid-summer. By mid-October, temperatures had fallen to 8^{o}C. (Figure 2).

Wind speed and direction are limiting factors in the ability to sample. Approximately six trips were made during the course of the summer when wave conditions in the lake made sampling impossible. Wave

TABLE I

PHYSICAL CONDITIONS

Sample Key

IJC Cladophora Study - Oakville, Lake Ontario, 1981.

1. Shoreline 0.5m
2. 5m contour at 1m
3. 5m contour at 4m
4. Offshore at 1m

Date	Sample	Water Temp.(1m) °C	Air Temp. °C	Wind Speed kph (est.)	Wind Direction	Secchis Disc m
May 22	1					
	2	9.5	21			3.3
	3	8.5				
	4	9.5				3.3
June 1	1	14		5	NE	
	2	12	20			3.25
	3	11.5				
	4	11.5				3.25
June 9	1					
	2	7.5	17.3		WNW	2.9
	3	6.5				
	4	7.5				3.0
June 15	1	11		8	WSW	
	2	10	22			2.3
	3	9				
	4	10.3				2.3
June 23	1	8.5				
	2	6.5	19			3
	3	4				
	4	6				4.3
July 3	1	15				
	2	12	22			1.7
	3	11				
	4	10.5				2.4

TABLE I - cont'd.

Date	Sample	Water Temp. (1m) °C	Air Temp. °C	Wind Speed kph (est.)	Wind Direction	Secchis Disc m
July 8	1	16				
	2	16	22			2.3
	3	12				
	4	16				2.3
July 13	1	14				
	2	11.5	21			3
	3	9.5				
	4	12				4
July 22	1	16				
	2	12	20			3
	3	12				
	4	10				2.5
July 26	1	18				
	2	16	18			2.1
	3	16				
	4	16				2.7
August 2	1	21				
	2	20	24			2.0
	3	18				
	4	20				1.6
August 10	1	20				
	2	18	25	8	SW	2.0
	3	18				
	4	18				2.0
August 24	1	20			NE	
	2	18	21			2.5
	3	18				
	4	18				2.7

TABLE I - cont'd

Date	Sample	Water Temp. (1m) °C	Air Temp. °C	Wind Speed kph (est.)	Wind Direction	Secchis Disc m
Sept. 15	1			5	NE	
	2					2.5
	3					
	4					2.5
Sept. 21	1			8	SW	
	2	15	12			3.1
	3	15				
	4	12				3.2
Oct. 5	1			10	SE	
	2	12	15			3.0
	3	10.5				
	4	11.0				3.0
Oct. 13	1					
	2	7	8	20	SE	2.0
	3	7				
	4	7				2.0

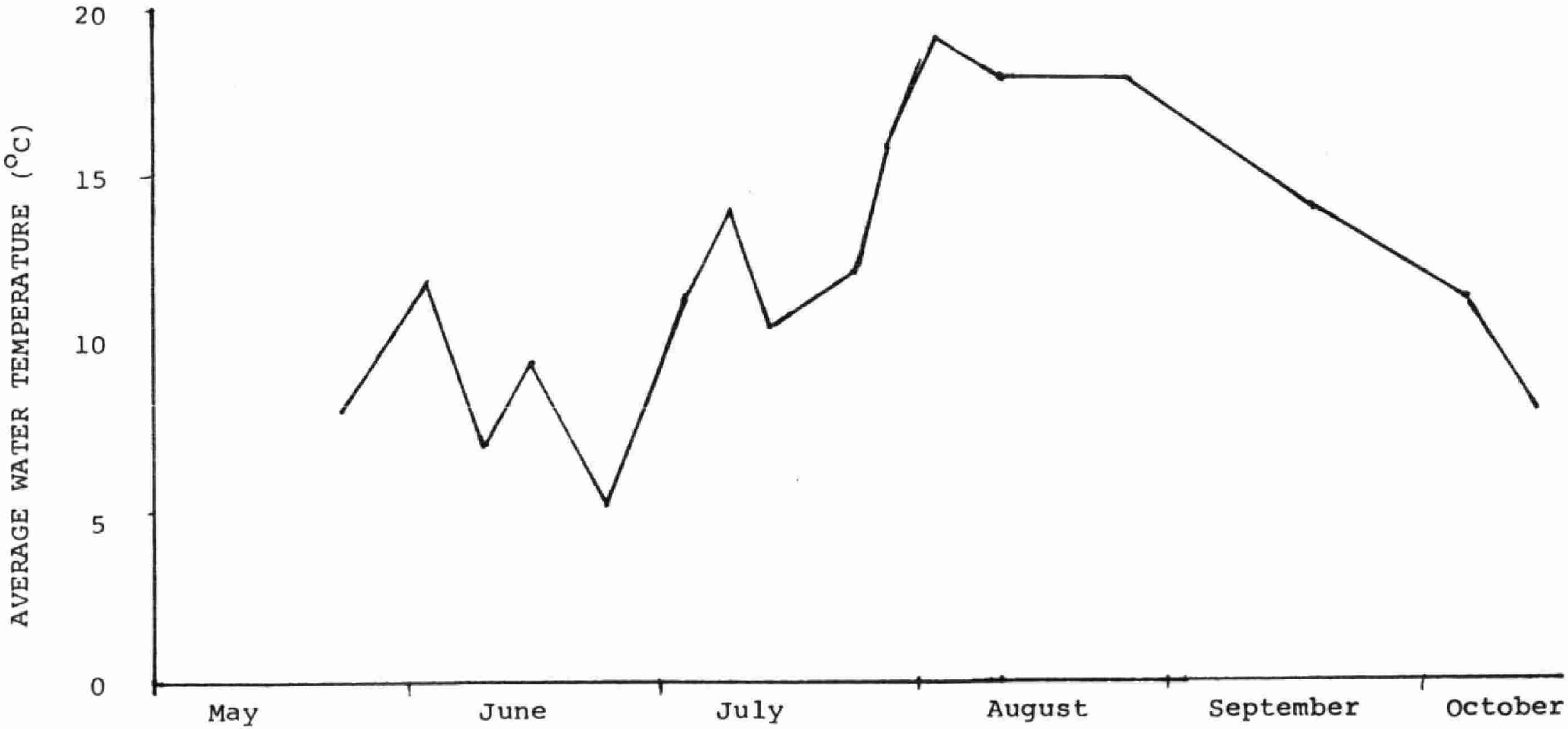


Figure 2: MEAN WATER TEMPERATURE AT 5M SITE - OAKVILLE

heights of greater than about 0.5m effectively prevents work by a diver from a small boat and makes it impossible to collect samples in surf at the shoreline. Difficulties in this regard were more common during the late summer and fall period.

It will be noted that the turbidity of the water varied considerably as measured by secchi disc reading from a maximum clarity of 4.3m to a minimum of 1.6m. Transparency is a function of previous and current wind speed and direction. As sampling could only be done in periods of calm weather or offshore winds, the water clarity reported is probably not typical of energy available for Cladophora growth.

Results of the light transmittance versus depth are found in Appendix iv. These data were collected with the aim of developing a relationship between secchi depth and light transmittance so that secchi data could be used to convert solar insolation data into estimates of light energy available for photosynthesis to develop primary production relationships. Due to the lack of production data, it was not possible to apply this information but it is included for the record.

Water Quality

Water samples were taken at four locations, 0.5m (at shoreline) at the 5.0m station 1m and 4m below surface and at the offshore site at 1.0m. The results of all chemical analyses are reported in Table II. Significant variations in the nutrient resources of the water are demonstrated on individual sampling dates though major trends either seasonal or with depth on any one day are not apparent (See Table II). There is some evidence of enrichment at the shoreline during the period when the algae is growing actively and when accumulations were degrading as is evidenced by TKN, TP and DRP. The sample collected October 13 also shows very high NO_3 and phosphorus levels suggesting that it was affected by some nutrient source on this occasion.

Trends Noted in Water Quality Analyses

	With Depth	Seasonal
NO_3	Variable. No apparent trend.	Variable. No apparent trend. General range 0.1-0.5 ppm.
NH_3	Very variable. No trend.	Variable. .01 to .30 ppm. No seasonal trend.
TKN	Shore sample consistently high and decreased with distance from shore 'til early Aug. No diff. thereafter.	General trend of higher values 'til mid-Aug., lower thereafter.
Tot.P.	Shore sample significantly higher 'til early Aug. No difference thereafter.	Shore sample decreases with season. No trend offshore.
DRP	Shore sample significantly higher 'til mid-July. (Growing season). Consistent thereafter.	Variable. Trend to midsummer high.
Cond.	Max. 10 μmho for offshore samples on any day.	310-400 μmho - variable. No seasonal trend

TABLE II -

SUMMARY OF WATER QUALITY ANALYSIS

IJC Cladophora Study - Oakville, Lake Ontario, 1981.

Sample Key
1. Shoreline 0.5m
2. 5m contour at 1m
3. 5m contour at 4m
4. Offshore at 1m

Date	Sample	Lab No.	NO_3	NH_3	TKN	TP	DRP	Cond. (µmho)
					ppm			
May 22	1	R21- 8		.004	.66	.074	.061	340
	2	9	.340	.062	.26	.012	.006	330
	3	10	.332	.064	.25	.014	.008	330
	4	11	.336	.058	.25	.011	.002	330
June 1	1	R22- 90	.210	.220	.51	.043	.021	325
	2	91	.264	.068	.27	.016	.008	330
	3	92	.290	.010	.31	.020	.010	335
	4	93	.269	.090	.30	.014	.008	335
June 9	1	R23-191	.095	.112	.67	.068	.060	325
	2	192	.306	.062	.29	.017	.010	320
	3	193	.304	.064	.28	.020	.013	320
	4	194	.285	.074	.28	.018	.012	320
June 15	1	R24-228	.227	.144	.49	.048	.031	330
	2	229	.223	.076	.32	.022	.011	330
	3	230	.245	.004	.36	.021	.012	335
	4	231	.285	.052	.43	.025	.015	330
June 23	1	R25- 21	.265	.004	.75	.088	.040	390
	2	22	.318	.006	.40	.035	.005	390
	3	23	.344	.006	.25	.014	.001	400
	4	24	.322	.010	.24	.016	.001	395
July 8	1	R27- 95	.832	.004	1.41	.148	.067	350
	2	96	.175	.118	.35	.018	.009	320
	3	97	.188	.160	.43	.026	.012	320
	4	98	.167	.104	.32	.016	.009	330

TABLE II - cont'd.

Date	Sample	Lab No.	NO_3	NH_3	TKN	TP	DRP	Cond.
					ppm			
July 18	1	R28- 68	.190	.162	.41	.032	.017	345
	2	69	.237	.120	.35	.022	.012	330
	3	70	.272	.110	.36	.025	.015	330
	4	71	.229	.078	.27	.014	.006	330
July 22	1	R29-127	.243	.340	1.20	.110	.026	360
	2	128	.250	.142	.42	.028	.015	330
	3	129	.252	.174	.39	.024	.016	330
	4	130	.214	.124	.38	.023	.012	330
July 26	1	R30-212	.251	.004	.51	.056	.013	320
	2	213	.195	.004	.37	.026	.013	330
	3	214	.180	.002	.38	.023	.012	320
	4	215	.155	.004	.40	.027	.018	330
August 2	1	R31- 1	.320	.006	.50	.052	.026	320
	2	2	.275	.006	.35	.028	.020	320
	3	3	.260	.006	.33	.029	.019	320
	4	4	.108	.006	.35	.025	.015	320
August 10	1	R32- 82	.340	.006	.32	.012	.019	325
	2	83	.220	.006	.34	.013	.022	330
	3	84	.325	.006	.42	.024	.035	325
	4	85	.190	.008	.31	.014	.021	325
August 24	1	R34-143	.001	.010	.40	.035	.020	310
	2	144	.125	.008	.41	.030	.016	315
	3	145	.004	.004	.42	.028	.021	310
	4	146	.002	.010	.49	.028	.017	315
Sept. 15	1	R37- 1	.101	.060	.29	.020	.010	315
	2	2	.080	.060	.32	.021	.004	315
	3	3	.176	.038	.28	.017	.005	320
	4	4	.044	.064	.30	.016	.004	310

TABLE II - cont'd.

Date	Sample	Lab No.	NO_3	NH_3	TKN	TP	DRP	Cond.
			ppm					
Sept. 21	1	R38-127	.127	.090	.30	.022	.003	315
	2	128	.122	.060	.29	.018	.003	315
	3	129	.126	.048	.27	.019	.003	315
	4	130	.117	.038	.28	.016	.001	315
October 5	1	R40-118	.156	.082			.003	310
	2	119	.164	.062			.002	310
	3	120	.218	.006			.002	320
	4	121	.156	.018			.002	315
October 13	1	R41-102	.473	.002	.25	.024	.013	340
	2	103	.453	.004	.24	.200	.195	335
	3	104	.420	.004	.24	.131	.118	330
	4	105	.339	.008	.27	.168	.160	340

Cladophora Biomass

Three replicate samples for standing crop biomass were collected on fourteen occasions from June 1 to September 29 at four depths. Heavy floating algae accumulations along the shore covered the 0.5m site during early July and decomposing solids covered the bottom at this station until washed away after early August. For this reason, some changes in sampling procedures were made between a location on the bottom immediately offshore and samples of fringe growths at the surface of vertical-faced boulders. The changes in procedures developed when accumulations precluded the use of the horizontal bottom surface. The vertical face was not satisfactory as the lake level fell during the summer and decomposing algae affected the depth to which Cladophora could grow as a fringe. For these reasons, the results for the 0.5m depth should not be considered quantitative.

Samples taken at the 1.5, 3.0 and 5.0m depths presented no special problems and data obtained may be considered to be representative of growths at these depths within the variability present on any sampling date.

The results of combined replicate samples taken on each sampling occasion are presented in Table III for wet weight, dry weight and volume. Standing crop biomass for the three depths for which consistent samples are available are plotted in Figure 3 as oven dry weight in gm./m^2, and Figure 4 as volume in ml./m^2.

TABLE III -

SUMMARY OF ALGAE ANALYSES

IJC Cladophora Study - Oakville, Lake Ontario, 1981.

Date	Depth m	Wet Wt. g/m^2	Dry Wt. g/m^2	Volume ml/m^2	Dry Mat. %	Ash %	Org. % D.W.	Org. g/m^2	N %	N %org.	P %	P %org.
May 22		Insufficient growth to sample.			Cladophora-Ulothrix mix.							
June 1	0.5	170.0	39.7	164.0	23.4	26	74	29.4	3.20	4.32	0.22	0.30
	1.5	391.1	122.3	356.0	31.3	67	33	40.4	1.11	3.36	0.08	0.24
	3.0	152.7	50.1	132.0	32.8	73	27	13.5	1.60	5.93	0.16	0.59
	5.0	77.6	23.5	73.3	30.3	67	33	7.8	1.93	5.85	0.24	0.73
June 9	0.5	334.9	72.5	314.7	21.6	31	69	50.0	4.00	5.80	0.30	0.60
	1.5	756.3	188.4	733.2	24.9	57	43	81.0	1.79	4.16	0.11	0.26
	3.0	227.2	55.3	221.3	24.3	53	47	26.0	2.25	4.79	0.16	0.34
	5.0	119.5	28.8	113.3	24.1	55	45	13.0	2.22	4.93	0.22	0.49
June 15	0.5	756.0	156.5	729.3	20.7	49	51	79.9	3.53	6.92	0.23	0.45
	1.5	1239.3	192.7	1253.3	15.5	49	51	98.3	3.00	6.00	0.18	0.35
	3.0	384.1	63.6	370.7	16.6	46	54	34.3	2.72	5.04	0.15	0.28
	5.0	322.1	46.8	301.3	14.5	41	59	27.6	4.56	7.73	0.42	0.71
June 23	0.5	1124.3	206.3	1053.3	18.3	56	44	90.8	2.00	4.55	0.15	0.34
	1.5	1438.6	277.7	1333.3	19.3	59	41	113.9	1.86	4.54	0.11	0.27
	3.0	517.3	70.9	506.7	13.7	38	62	44.0	2.27	3.66	0.14	0.23
	5.0	320.7	42.5	313.2	13.3	41	59	25.1	3.40	5.76	0.29	0.49
July 3	0.5	534.4	59.7	520.0	11.2	30	70	41.8	3.39	4.84	0.22	0.31
	1.5	214.3	25.3	210.7	11.8	29	71	18.0	3.55	5.00	0.23	0.32
	3.0	80.3	10.7	78.7	13.3	33	67	7.2	4.20	6.27	0.27	0.40
	5.0	120.7	17.6	112.0	14.6	43	57	10.0	2.50	4.39	0.21	0.37
July 8	0.5	299.6	83.6	280.0	27.9	53	47	39.3	2.56	5.45	0.17	0.36
	1.5	278.3	79.7	272.0	28.6	59	41	32.7	1.45	3.54	0.10	0.24
	3.0	154.4	36.9	148.0	23.9	43	57	21.0	2.39	4.19	0.11	0.19
	5.0	63.9	14.5	60.7	22.7	48	52	7.5	2.83	5.44	0.23	0.44

TABLE III - cont'd

Date	Depth m	Wet Wt. g/m^2	Dry Wt. g/m^2	Volume ml/m^2	Dry Mat. %	Ash %	Org. % D.W.	Org. g/m^2	N %	N %org.	P %	P %org.
July 13	0.5											
	1.5	590.3	153.9	533.3	26.1	67.5	32.5	49.2	1.46	4.49	0.12	0.37
	3.0	368.1	81.3	346.7	22.1	62	38	30.9	2.00	5.26	0.15	0.39
	5.0	147.1	30.5	136.0	20.7	52.5	47.5	14.5	2.25	4.74	0.17	0.36
July 22	0.5											
	1.5	750.1	194.7	686.7	33.0	70	30	58.4	1.92	6.40	0.19	0.63
	3.0	406.8	77.5	384.0	19.1	51.5	48.5	37.6	2.38	4.91	0.17	0.35
	5.0	46.0	10.7	43.7	23.3	53	47	5.0	2.61	5.55	0.23	0.49
July 26	0.5											
	1.5	181.7	34.8	173.3	19.2	50	50	17.4	2.65	5.30	0.19	0.38
	3.0	350.9	52.5	340.0	15.0	45	55	28.9	3.17	5.76	0.20	0.36
	5.0	50.0	10.4	48.0	20.8	51	49	5.1	3.14	6.41	0.27	0.55
Aug. 2	0.5											
	1.5	55.9	11.3	54.7	20.2	44	56	6.3	3.42	6.11	0.18	0.32
	3.0	82.5	14.9	80.0	18.1	46	54	8.0	2.66	4.93	0.30	0.56
	5.0	12.8	2.8	11.5	21.9	41	59	1.7	5.00	8.47	0.71	1.20
Aug. 10	0.5	165.2	33.7	166.7	20.4	18	82	27.6	4.57	5.57	0.28	0.34
	1.5	108.5	35.9	104.0	33.1	54	46	16.5	1.92	4.17	0.14	0.30
	3.0	96.3	28.8	94.7	29.9	44.5	55.5	16.0	2.60	4.68	0.21	0.38
	5.0	9.5	3.3	10.7	34.7	44	56	1.8	3.93	7.02	0.40	0.71
Aug. 24	0.5	226.7	38.5	217.3	17.0	21	79	30.4	3.68	4.66	0.27	0.34
	1.5	373.7	93.1	332.0	24.9	58	42	39.1	2.27	5.40	0.15	0.36
	3.0	253.7	59.7	234.7	23.5	49	51	30.4	2.74	5.37	0.19	0.37
	5.0	6.1	1.5	6.7	24.6	43	57	.9	4.82	8.46	0.54	0.95
Sept. 15	0.5	384.8	90.7	350.7	23.6	66	44	39.9	2.18	4.95	0.15	0.34
	1.5	85.5	18.8	81.3	22.0	42	58	10.9	4.05	6.98	0.25	0.43
	3.0	94.8	21.3	86.7	22.5	46	54	11.5	2.75	5.09	0.22	0.41
	5.0	28.7	7.2	25.3	25.1	53	47	3.4	4.29	9.13	0.49	1.04
Sept.29	0.5	Too rough.				56	44	-	2.50	5.68	0.15	0.34
	1.5	84.4	18.7	78.7	22.7	47	53	9.9	2.96	5.58	0.21	0.40
	3.0	61.9	14.7	61.3	23.7	56	44	6.5	3.29	7.48	0.25	0.57
	5.0	Insufficient growth.				58	42	-	3.76	8.95	0.35	0.83
	Mean				21.0		48.8		2.87	5.58	0.23	0.45
Oct. 13		Insufficient growth.(qual.)										

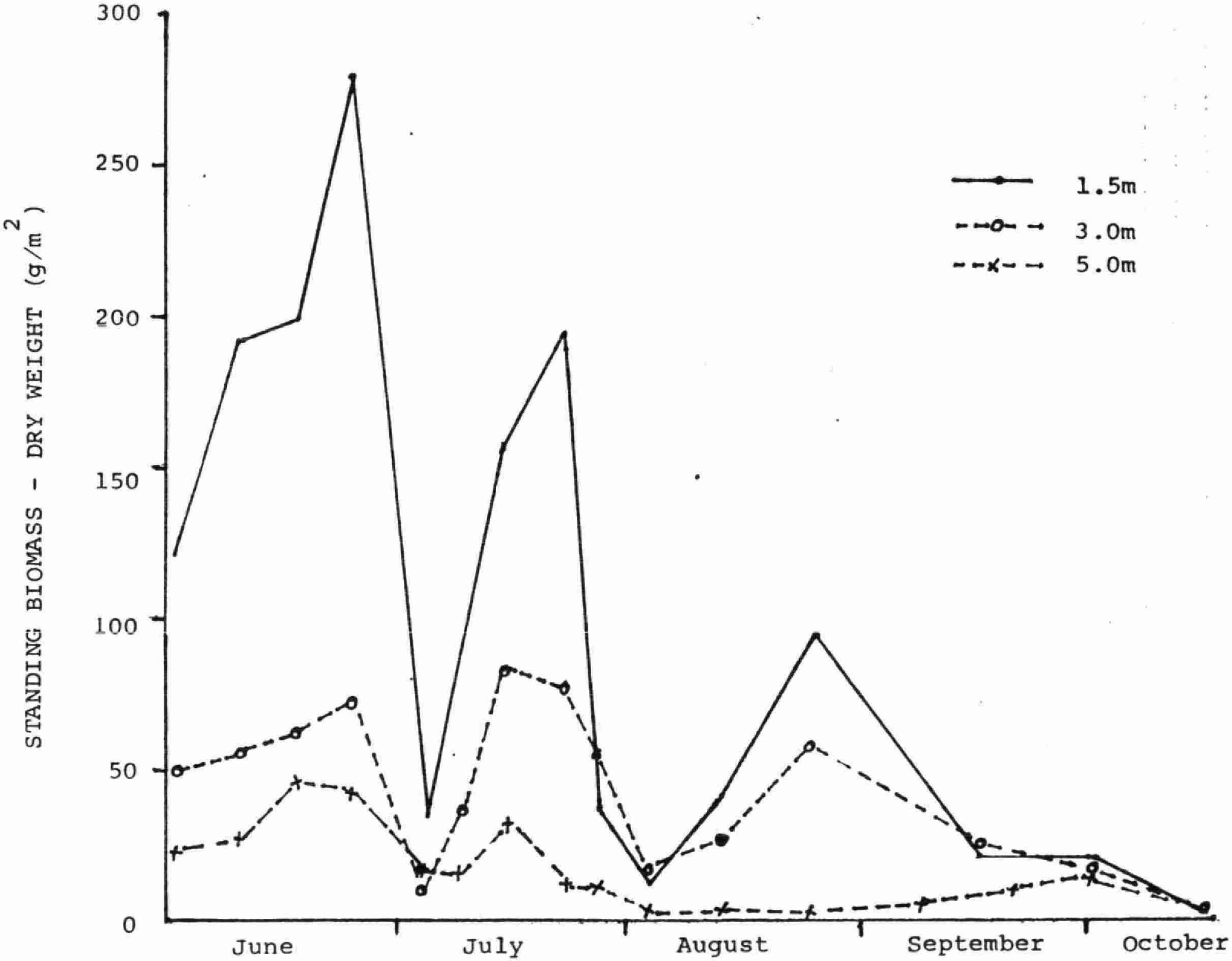


Figure 3: SEASONAL CLADOPHORA STANDING CROP - DRY WEIGHT

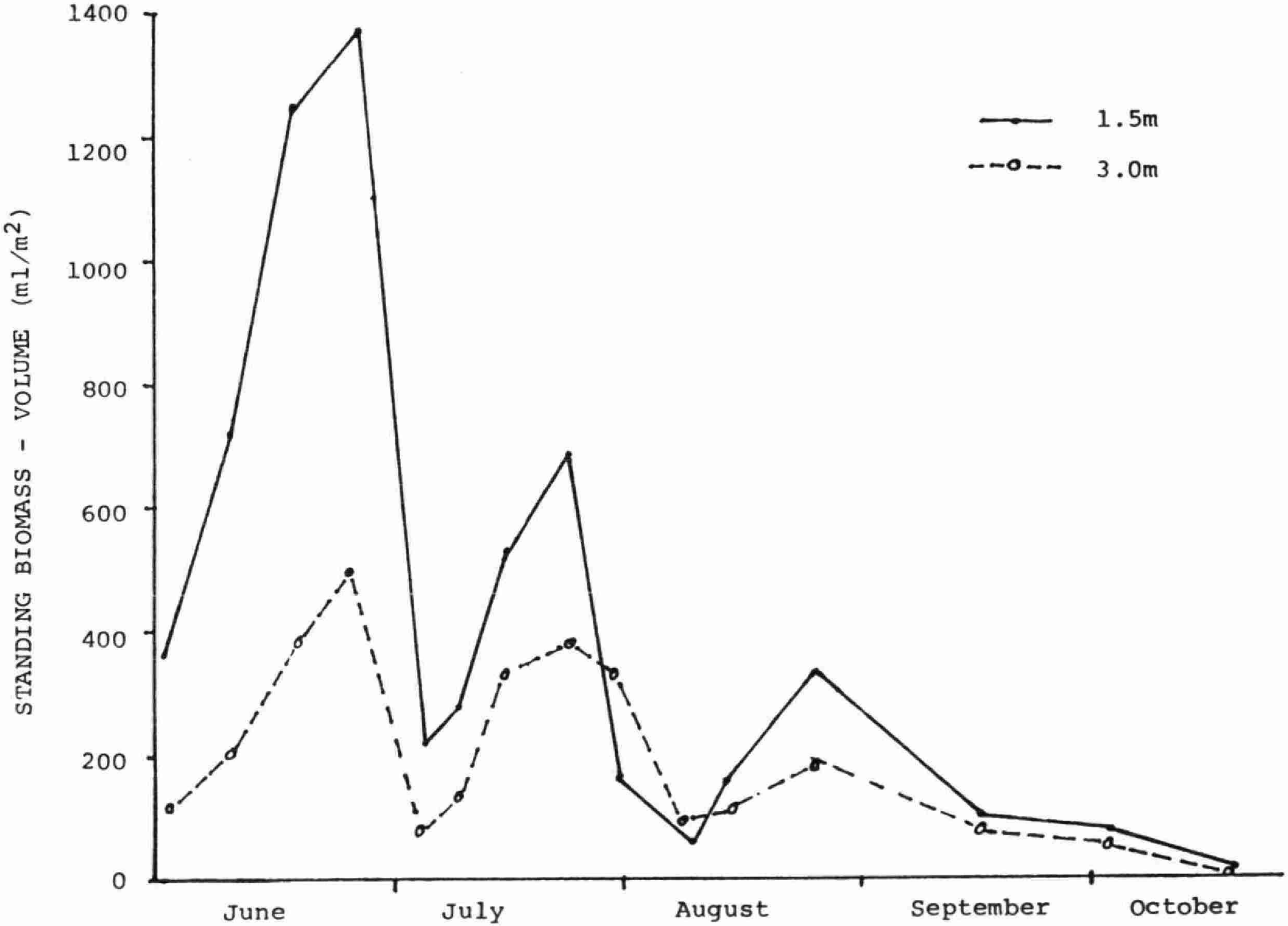
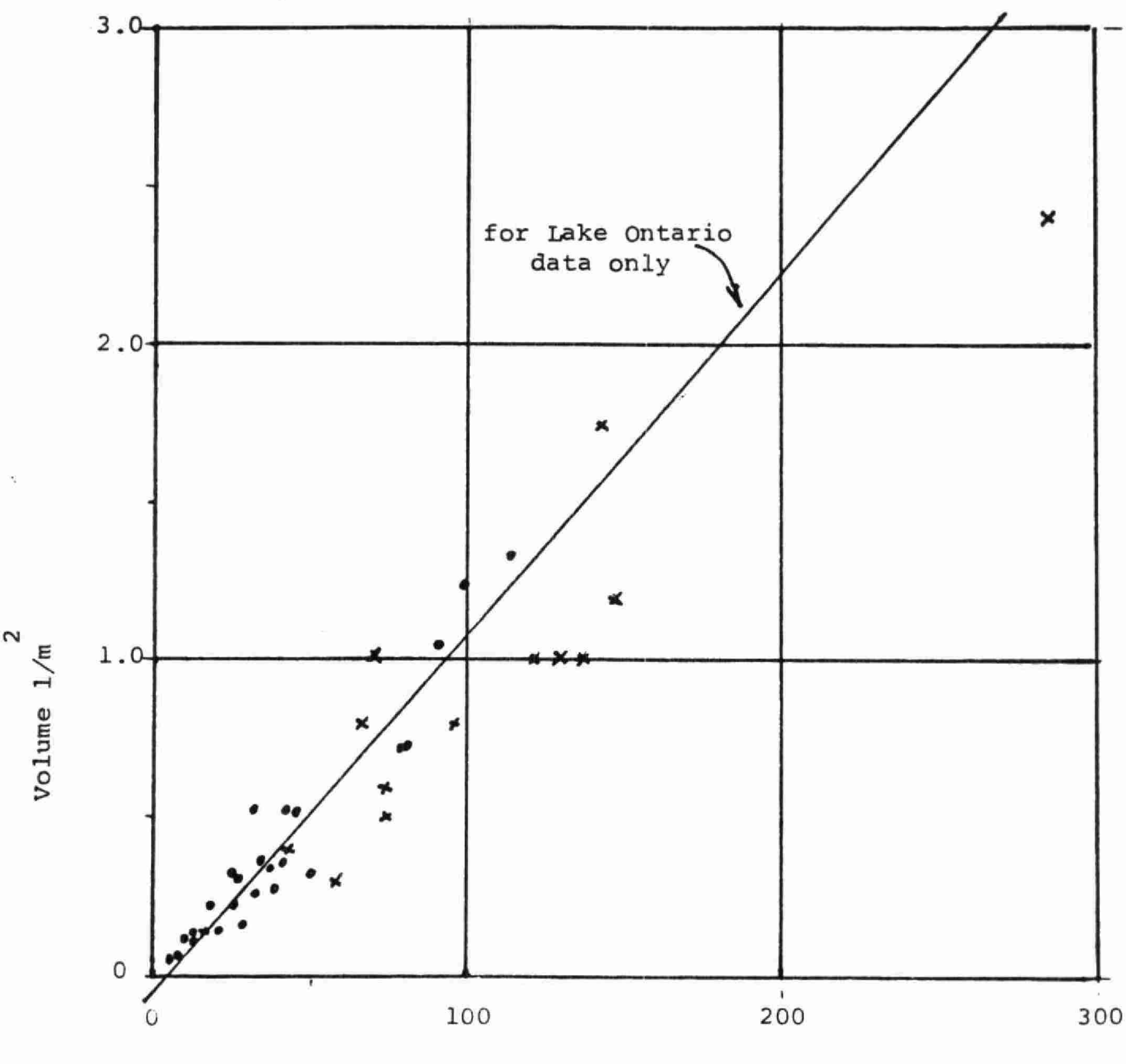


Figure 4: SEASONAL CLADOPHORA STANDING CROP - VOLUME

Figure 5: VOLUME & ORGANIC DRY WEIGHT RELATIONSHIP



Regression Line: $y = -0.043 + 0.0114x$; $r^2 = .94$

• Oakville, Lake Ontario 1981

× Rathfon Point, Lake Erie 1980

Tissue Nutrient Analysis

The results of analyses performed for total phosphorus, total nitrogen and loss on ignition are included in Table III. In some cases, duplicate samples from two quadrates at the same location were analysed to assess variability. The results were found to show reasonable agreement and were averaged for reporting purposes.

Ash levels were found to vary from 18% to 73% (mean 48.7%) of dry weight and were generally about 50% of the sample. This variability of ash levels appears to be inherent in collections and results from the entrainment of fine silty clays, snail shells, holdfast attachments etc. which cannot be removed by simple washing and hand picking of obvious inorganics. This will have an obvious effect on the percent values of tissue phosphorus contained by the Cladophora plant. For this reason, percentages of both the sample as received and the ash-free (organic) values are reported.

The tissue nitrogen values noted range from 1.1 to 4.8% (mean 2.87%) for samples as received, and 3.4 to 9.1 (mean 5.58%) on an ash-free basis. Phosphorus values noted range from 0.08% to 0.7% (mean 0.23%) for samples as received, and 0.24% to 1.2% (mean 0.45%) on an ash-free basis.

A trend is noted for increased nitrogen and phosphorus with depth. As production at the 3m and 5m location is reduced, the demand for tissue nutrient resources would be expected to be less.

DISCUSSION

The principal objectives for the L. Ontario Cladophora study in 1981 were to establish a set of baseline data which would provide a quantitative basis for measurement of changes in Cladophora growth between past surveys, the present and future measurements. It was intended that this be based on regular seasonal insitu biomass measurement and an estimate of production based on repeated sampling of identified lake bottom areas. In addition, the results would permit comparisons with previous tissue analysis of the Cladophora from both L. Ontario and L. Erie which might provide some guidance as to whether tissue phosphorus levels are within a range that reduced levels of lake fertility could exert a controling influence on production.

Procedures for determining insitu biomass have been established and used effectively. The accuracy of this procedure in taking replicates should be good. The procedure requires judgment on the part of the diver to select three areas 100% covered which are typical of the growth at that time and depth. The results (Appendix i) show the extent of variability between individual samples in each replicate to be quite large, frequently in the order of 100%. With a wide variation in sample variability, there will be difficulty in establishing a statistical basis for demonstrating change within the lake over time.

Data for replicate values are available from Owen's 1972 work in L. Ontario (15 samples with 3 or more reps.), L. Erie, Rathfon Pt., 1979 ($\pm$40 samples) and L. Ontario (41 samples) for an evaluation of the confidence that may be placed in the value of three replicated samples. This analysis would appear to be important to determine if changes in time

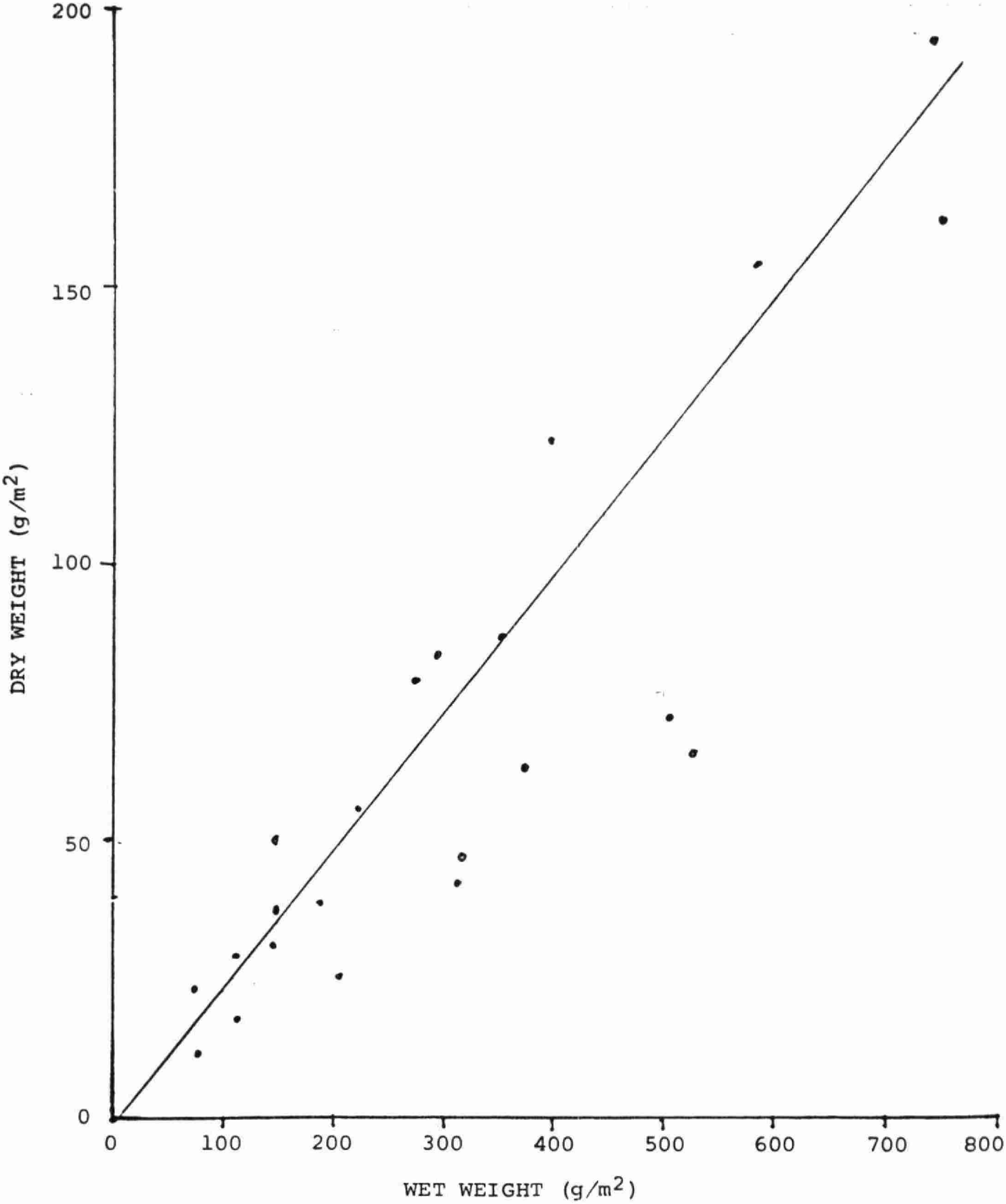
are to be interpreted from biomass sampling at a single location.

Thought should also be given to the most practical means of reporting biomass. Previous evaluations of comparisons of wet, oven dry, ash-free dry weight and volume have been made and discussed (Limnos 1981, Milner 1980), which suggests that an accurate representation of ash-free, dry weight can be simply done using a volume measurement. Figure 5 is a plot of data for values measure in the 1979 and 1981 field studies which demonstrates the accuracy of volume measurements. It is suggested that either ash-free weight or volume be adopted as an expression of biomass as inorganic solids such as sand, silt, holdfast attachments and snail shells which cannot be washed out of the sample adds disproportionately to the dry weight of samples and causes at least some of the variability noted. While future sampling should include all measurements and a data base built that would provide confidence in data reported, the ultimate adoption of the volume measurement technique would allow for a rapid and accurate means of collecting biomass information without a requirement for oven drying and ashing procedures in the laboratory.

An examination of the wet weight/dry weight relationship (Figure 6) for a number of the early season values at various depths indicates a broad scatter of values. This suggests that extra cellular moisture is not removed equally for all samples and is therefore not a suitable routine measurement to use.

A comparison of 1981 data was made with Owen's information of 1972 with respect to biomass. His samples were taken once at the same location on July 12. A very similar dry weight biomass was found

Figure 6: WET WEIGHT - DRY WEIGHT RELATIONSHIP



(Figure 7) which suggests that no major change has occurred in the interval. Some care should however be taken in drawing a firm conclusion as our seasonal data show some major changes going on during July and the observation could be happenstance.

A comparison with seasonal data for L. Erie (Figure 8) shows a more regular production in L. Erie which appears to relate to one major sloughing period happening first in the shallower water. Standing crop for the nearshore sample reached a higher biomass, but was surpassed on several occasions later in the summer. Standing crop at 3m in L. Ontario never reached the level of L. Erie. On the basis of one year's data for each lake, it may be concluded that Cladophora is more abundant in L. Erie.

There does not appear to be any relationship between the development of Cladophora biomass and its physical environment. Temperatures recorded on the sampling dates in L. Ontario were highly erratic. The mean of top and bottom values was noted to be highest at 18-19°C during August, but was as low as 5°C in the latter part of June after which the major release of algae occurred. Whether these occurrences are related factors is now known. Subsequent releases do not appear to be related to water temperatures either at the upper level of tolerance believed to be about 20°C or at the lower level of active growth in the order of 10°C. It should be noted that temperatures available are those recorded the day of sampling. Changes occur very quickly in L. Ontario and variations between the sampling dates are not known, although it is unlikely that they remained above the 20°C tolerance level for any significant period of time.

Figure 7: DRY WEIGHT OF BIOMASS LAKE ONTARIO OAKVILLE LOCATION

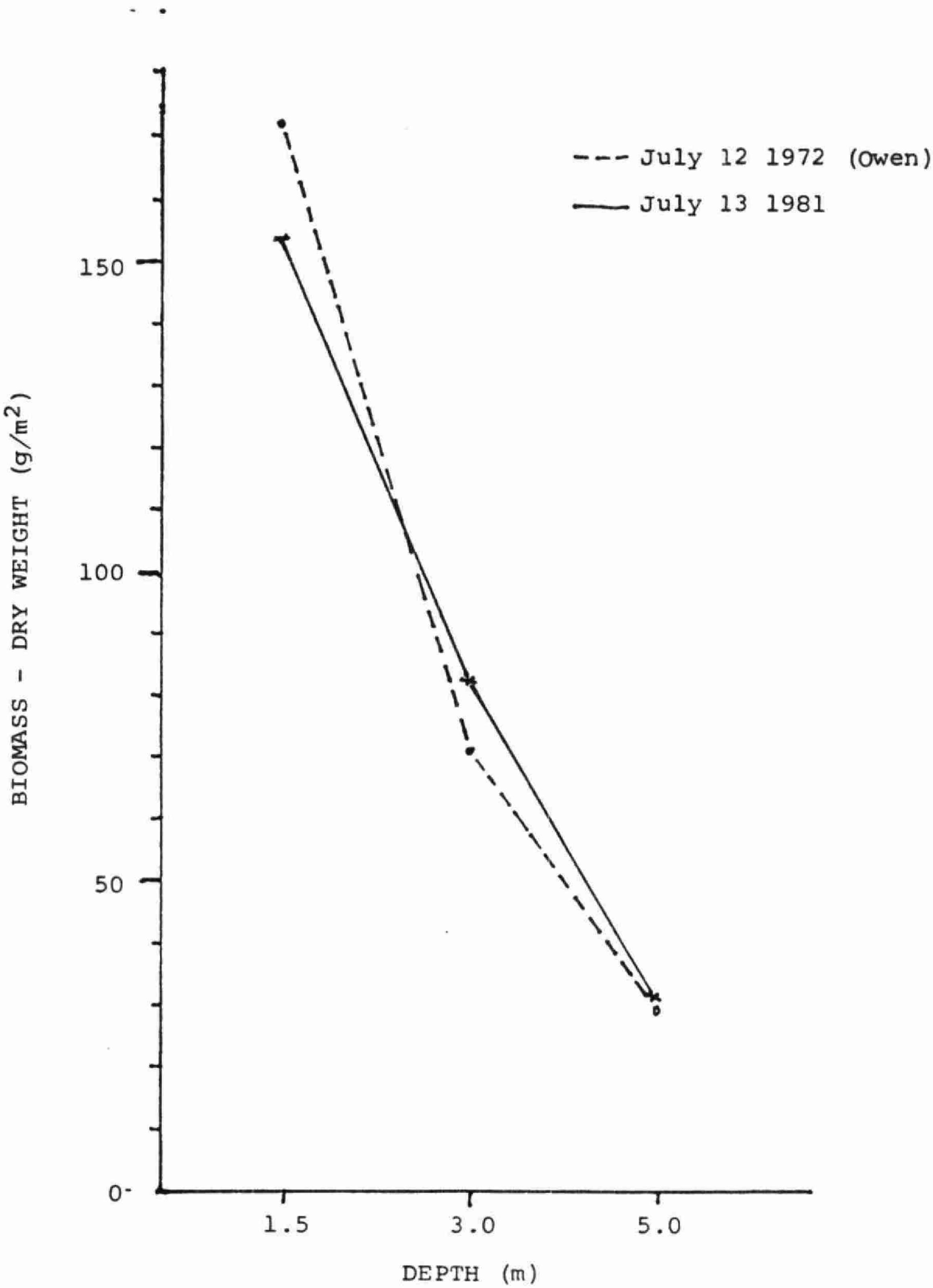
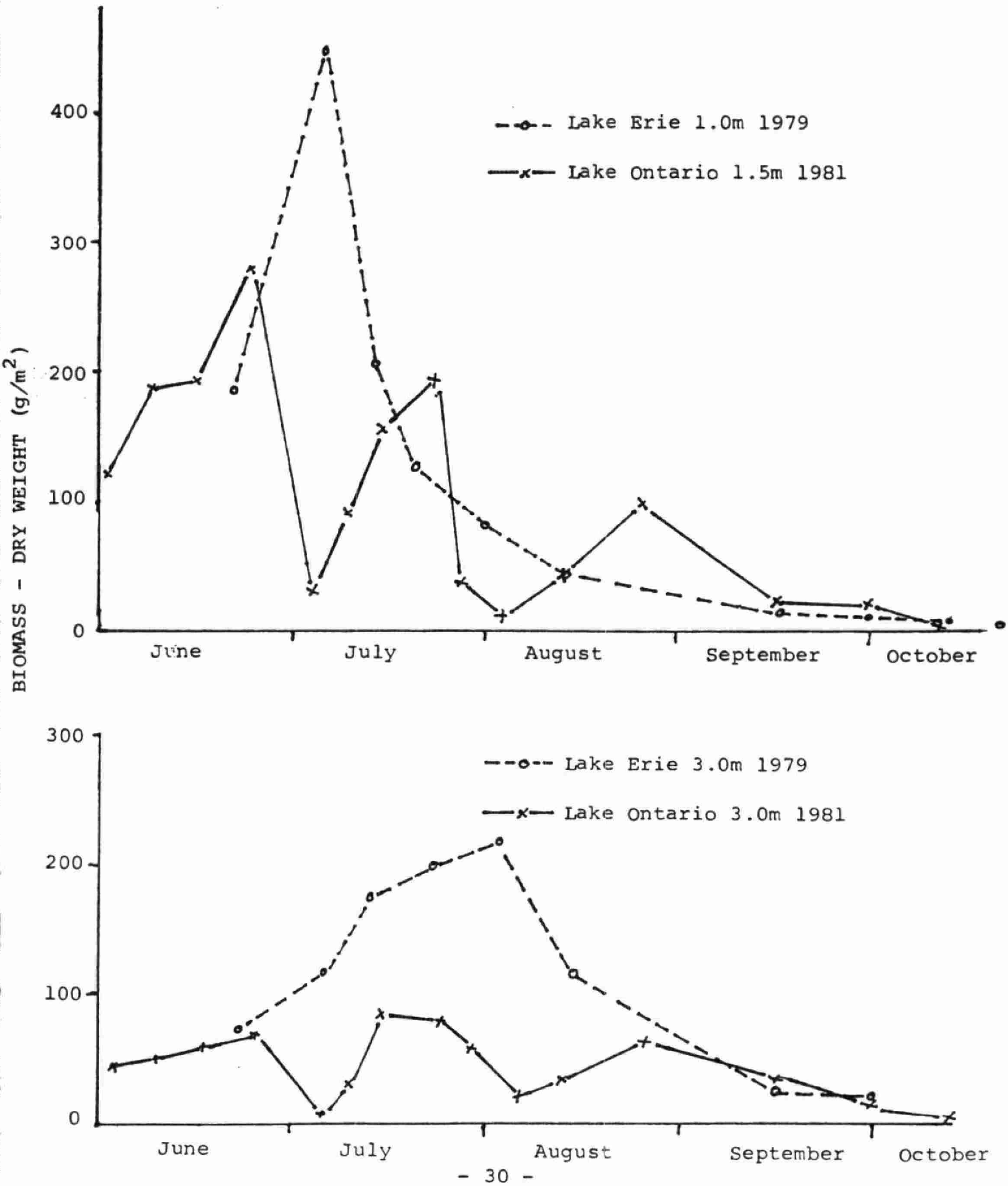


Figure 8: COMPARISON OF STANDING CROP BIOMASS

LAKE ERIE & LAKE ONTARIO



Light attenuation based on the mean secchi disc readings during the June-July period was 1.9 in L. Erie (1979-80) and 2.6 for L. Ontario (1981), suggesting that light was probably not a factor controling growth in L. Ontario.

A comparison made of the nitrogen and phosphorus resources in L. Ontario and the two-year average for L. Erie provides the following mean values for conditions from the start of growth to the end of July.

Mean Nutrient Concentrations

May - July

	NO_3	NH_3	TKN	TP	DRP
L. Ontario:	.259	.070	.355	.021	.010
L. Erie:	.205	.017	.324	.020	.003

It will be noted that all fertility measurements compared were higher in L. Ontario during the growing season than in L. Erie with both ammonia and soluble phosphorus being in excess by a factor of three. As available phosphorus in particular is believed to be a limiting factor in growth, it must be concluded that this nutrient in L. Ontario is at least three times the requirement for luxurious growth and that changes in available phosphorus brought about by limiting sources are unlikely to control the growth of Cladophora in L. Ontario.

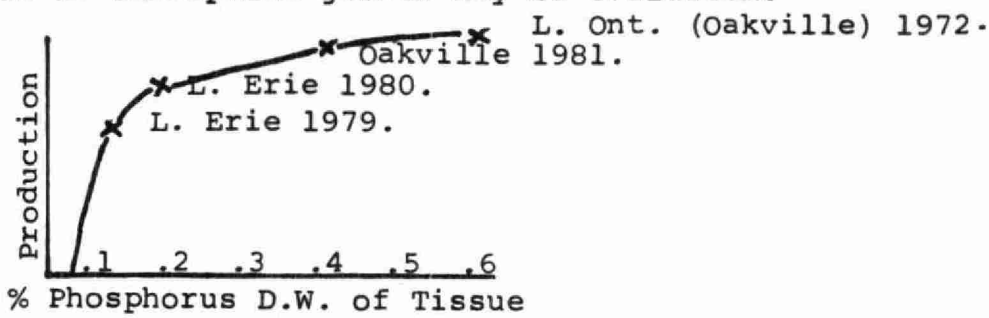
The presence of plant nutrients in the lake may be expected to be reflected in the tissue concentrations noted from analysis. (Fitzgerald 1970, Auer in press). Cladophora is able to accumulate luxury concentrations of phosphorus and to utilize it subsequently for growth. A developing means of evaluating the potential of waters to support nuisance quantities of Cladophora is tissue concentration of phosphorus

and a mathematical model for production based on this supposition has been developed (Auer in press).

An analysis of tissue phosphorus data from Lake Erie and Lake Ontario shows a considerable difference, with Ontario tissue containing more than twice the phosphorus found in tissue analysis for Lake Erie samples during the growing season. (Table IV and Figure 9). This is not reflected in higher production, but suggests that a significant reduction in available phosphorus will be required before a reduction in biomass is effected.

It is of interest to note, however, that when the 1981 data are compared to 1972 data of Owen's for the same site, it is significantly less suggesting that while it has not reached a critical concentration, a reduction apparently in response to phosphorus control programs has occurred.

Culture work by Auer (1982) has developed a curve for critical tissue nutrient level as indicated below. When tissue concentration for the Great Lakes is plotted on the curve, the nutrient resources available in relation to Cladophora growth may be evaluated.



To validate the model for growths in whole lake systems, data for more than a single season are required. If the relationships noted above are found to be valid, a means of predicting the requirements for control based on phosphorus limitation will have been achieved.

TABLE IV

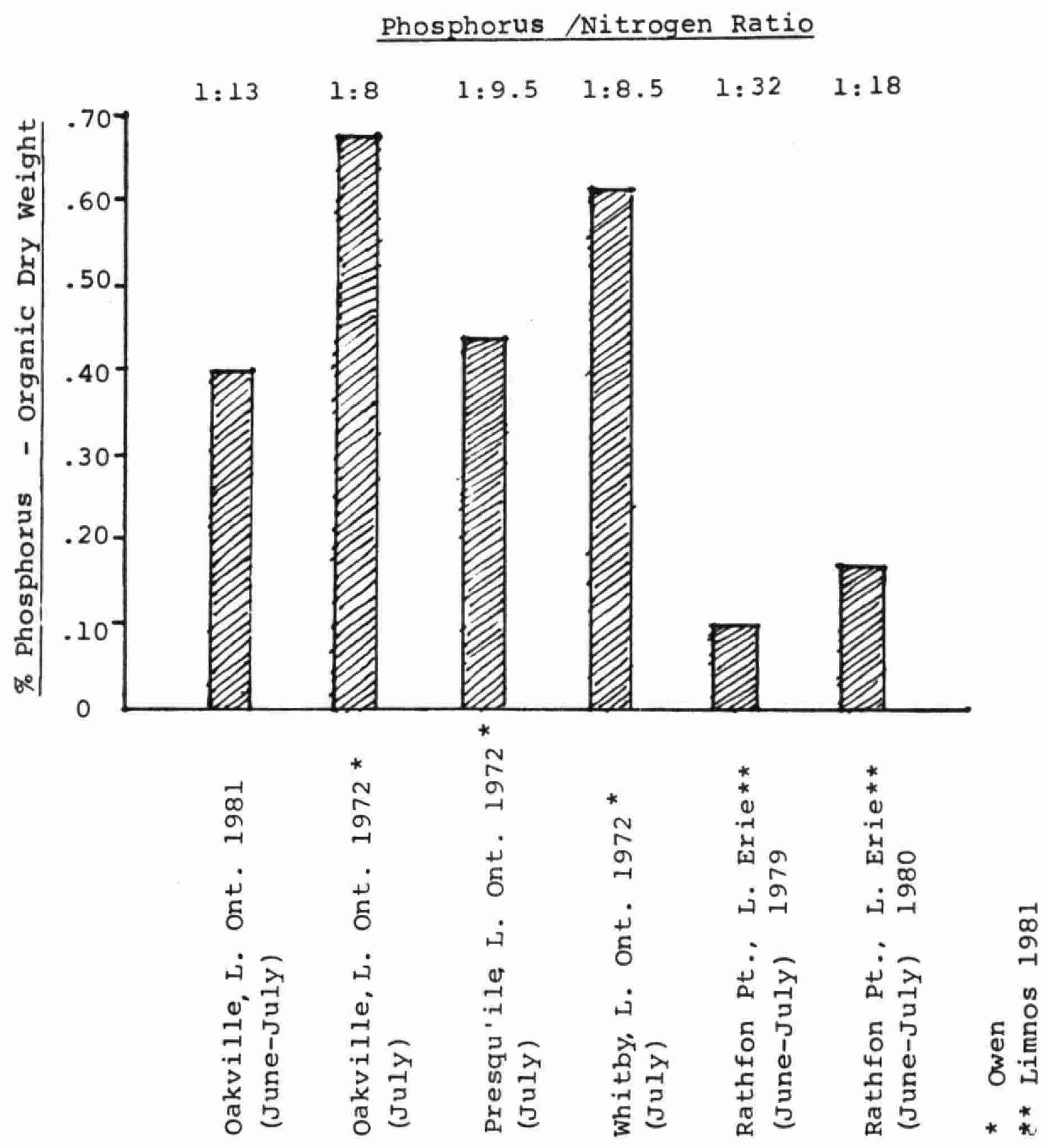
NITROGEN AND PHOSPHORUS (June-July)

	% As Received			% of Organic			
Nitrogen	Mean	Min.	Max.	Mean	Min.	Max.	n
Oakville, Lake Ontario, 1981	2.60	1.11	4.56	5.19	3.54	6.92	33
Oakville, Lake Ontario, 1972	2.00	-	-	5.44	-	-	13
Rathfon Pt., Lake Erie, 1979	1.87	1.23	2.58	2.88	2.0	3.6	20
Rathfon Pt., Lake Erie, 1980	2.03	1.56	2.82	2.95	2.1	3.5	24
Phosphorus							
Oakville, Lake Ontario, 1981	0.19	0.08	0.42	0.40	0.19	0.73	33
Oakville, Lake Ontario, 1972	0.26	-	-	0.67	-	-	13
Rathfon Pt., Lake Erie, 1979	0.06	0.02	0.12	0.10	0.03	0.21	20
Rathfon Pt., Lake Erie, 1980	0.11	0.07	0.24	0.17	0.09	0.35	24

Ratio P:N

Oakville, 1972: 1:8
Oakville, 1981: 1:13
Rathfon Pt., 1980: 1:32
Rathfon Pt., 1979: 1:18

Figure 9: TISSUE PHOSPHORUS - LAKES ONTARIO AND ERIE



Our attempts to measure production were fraught throughout the season with continuing difficulties and no meaningful data resulted from efforts in this regard. The problems encountered included loss of station markers, covering of production sites with loose algae which inhibits growth and makes it difficult to sample growing algae without including loose material. Another problem was the difficulty experienced by the diver working in cold water often requiring gloves to snip growth from a meter square area uniformly and without damaging the holdfast. To circumvent the problem of deposted loose alga, attempts were made to use boulders projecting above the bottom, but suitable boulders were not present at the 3 and 5m depths. On some occasions, visibility was very limited which made identification of the precise dimensions of the prepared meter square plot impossible in a seething mass of loose algae.

Attempts to harvest on rock faces at the shore were made difficult by seasonal changes in water levels, dense growth at the water line and much reduced growth below about 15 cm, which made production estimates based on a reasonable area uncertain. At the shore, some surf is almost always present which made it difficult for a collection to be made off a rock face without losing some in the waves or for the diver to maintain his position and keep the extraneous algae from being sucked into the collection intake on a horizontal face.

A professional diver was used for sample collections and a biologist supervised the above surface operations. This team was found to be satisfactory although I believe a biologist diver who had been trained in scientific sampling would be better able to observe and report conditions of Cladophora growth.

As the production estimate was unsatisfactory this year, some thought and experimentation was devoted to a means whereby an accurate measurement might be achieved. It has been concluded that the use of an artificial substrate will be necessary where harvesting of production can be done out of water. This has certain disadvantages in that the substrate and the condition in which it grows is not truly representative of the quantity that would be produced per square meter of bottom. On the other hand, it may be considered as an insitu bioassay capable of precisely measuring changes between years or decades, changes within a season and to provide a means of assaying and comparing algae growth potential within a lake and between lakes. Thought needs to be given to detailed design and procedures for anchoring and relocating, as the substrate would have to remain in position in a rugged, exposed location over a period of years. A simply designed substrate suitable for this purpose was built and observed on several occasions. It was subsequently lost as the temporary anchoring procedures used were not adequate for long-term positioning.

EVALUATION OF A FATHOMETER TO DETERMINE CLADOPHORA DISTRIBUTION

A method for doing surveys of aquatic plant distribution was developed in Florida (Maceina 1980) and the methodology subsequently employed by Limnos in surveys of macrophyte growths. The Florida studies identified accumulations of Lyngbia over a soft bottom which suggests that in our conditions of hard bottom, it might be possible to identify loose and growing Cladophora. If the procedure would work, it would provide a rapid means of surveying distribution independent of water clarity.

On July 6, an evaluation of this technique was undertaken using a Raytheon Precision Fathometer. Five runs from shore to 6m or more were made between the Oakville dock and the St. Lawrence Cement dock 7 km to the east. The tracings included two runs over the Park St. sample locations.

Figure 10 is included to illustrate the results of the fathometer tracing from the buoy used to mark the offshore water sample location to the shore at Park St.

It was concluded that the fathometer did not differentiate between the substrate and Cladophora in sufficient detail to permit an estimation of distribution on the bottom.

There are, however, several features of general interest which would appear to have been recorded. On July 6 when the transects were run, the majority of the biomass had loosened. Some had floated ashore and patchy growth and loose material was on the bottom. Many small clumps were observed floating suspended in the water column and large patches on the surface. The echo-sounder appears to have recorded suspended material in the water column out to a depth of about 4m which corresponds roughly to the depth to which the algae grows. This was probably a band of loose material being carried as a suspension by shoreline currents.

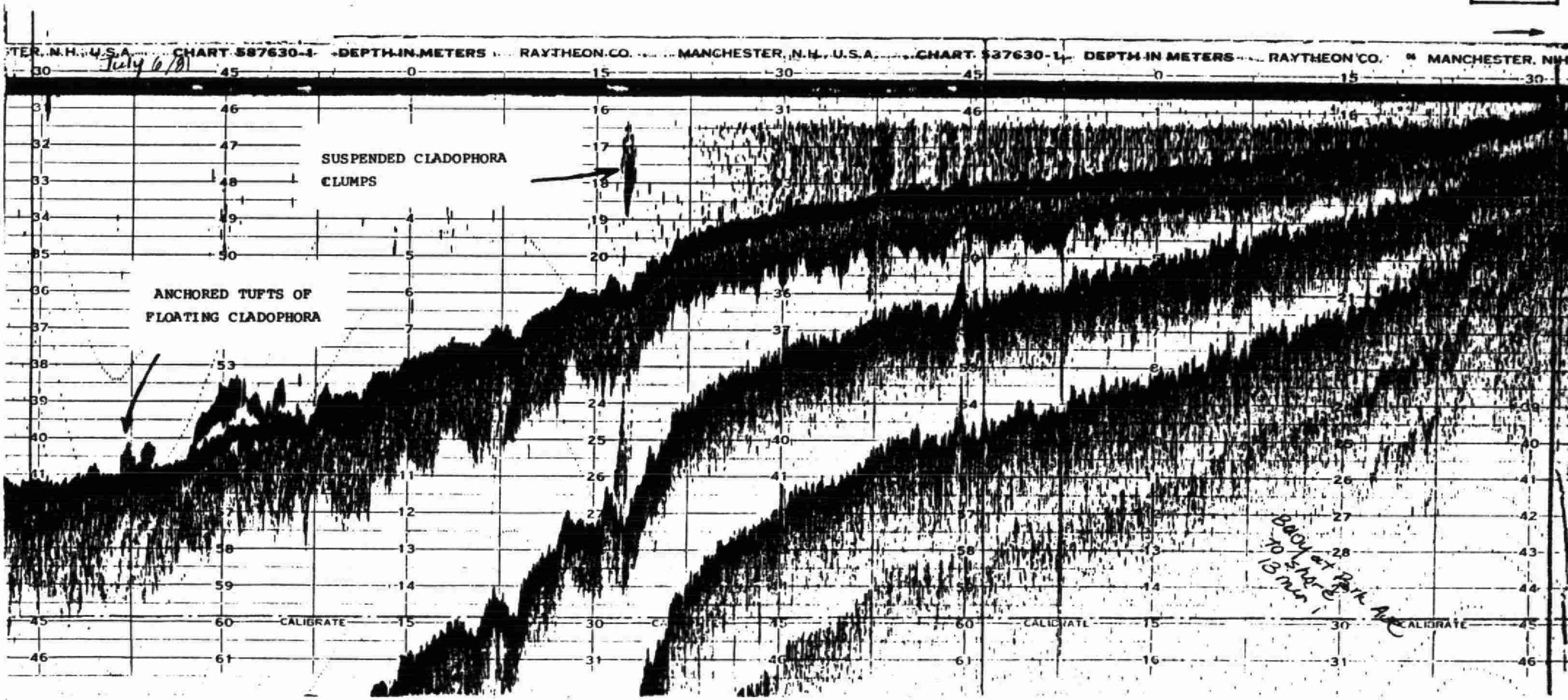
Peaks are noted projecting from the bottom at depths of less than 4m and are believed to be tufts of algae anchored but rising above the bottom suspended by accumulated gas. The feature offshore in about 9m is suggestive of a mass of algae which has moved down the slope or sunk

Figure 10: FATHOMETER TRACING OF PARK ST. LOCATION

MARKER BOUY TO PARK ST.

MARKER BUOY

PARK STREET



from the surface. Such masses of organic enrichment may well serve as enriched substrates that support the high populations of invertebrates commonly found in the nearshore sediments.

LITERATURE CITED

Auer, M. T. (1982). IAGLR - in press.

Carnes, C. J. and G. C. Milner (1980). Field and Laboratory Methods - Special Report #22. G. L. L. State University College at Buffalo.

Fitzgerald, G. P. (1970). Evaluations of the Availability of Sources of Nitrogen and Phosphorus for Algae. J. Phycol. 6:239-247.

Limnos Limited (1974). Cladophora in the Great Lakes. Summary Report for Gt. Lakes Research Advisory Board, I. J. C.

Limnos Limited (1981). Lake Erie Cladophora Studies. Report, Ontario Min. of the Environment, Feb. 1981.

Maceina M. (1980). Proceedings of the 15th Annual Meeting, Aquatic Plant Control, Research Planning and Operations Review, U. S. Army Corps of Engineers, Savannah, Ga.

Ministry of the Environment (1973). Reports of Cladophora Investigations in Ontario 1958-1967.

Neil, J. H. and G. E. Owen (1964). Distribution, Environmental Effects and Significance of Cladophora in the Gt. Lakes. Pub. #11, Gt. Lakes Res. Div., University of Michigan. (IAGLR)

Wizernak, C. T., D. R. Lyzenga and F. C. Polcyn (1974). Cladophora Distribution in L. Ontario. (IFYGL). Office of Research and Development, U.S.E.P.A., Washington, D. C.

APPENDIX i

REPLICATE CLADOPHORA BIOMASS DATA
(-1/4 m² basis)

DATE	0.5 m. WW	0.5 m. DW	0.5 m. VOL	1.5 m WW	1.5 m DW	1.5 m VOL	3.0 m. WW	3.0 m. DW	3.0 m. VOL	5.0 m. WW	5.0 m. DW	5.0 m. VOL
JUNE 1	33.0	8.0	31	30.8	9.0	27	40.4	13.5	38	14.3	4.1	14
	54.2	13.1	51	112.6	38.7	100	43.2	15.3	35	23.2	7.2	22
	40.3	8.7	41	149.9	44.0	140	30.9	8.8	26	20.6	6.3	19
JUNE 9	99.4	21.0	90	233.0	54.9	225	36.0	9.1	35	21.4	5.6	20
	92.9	21.1	90	172.7	43.4	170	66.5	16.9	61	30.9	7.0	30
	58.4	12.3	56	161.5	43.0	155	67.9	15.5	70	37.3	9.0	35
JUNE 15	226.2	42.7	210	297.3	46.4	295	131.8	20.8	127	73.6	16.1	64
	196.2	37.8	205	415.7	56.7	430	88.5	14.7	88	104.6	21.9	102
	144.6	36.9	132	216.5	41.4	215	67.8	12.2	63	63.4	13.2	60
JUNE 23	249.1	47.5	240	177.9	30.2	170	2420	33.2	240	47.5	7.2	45
	272.1	53.9	250	446.6	83.5	410	54.1	7.2	55	125.5	15.2	125
	322.0	53.3	300	454.6	94.6	420	91.9	12.8	85	67.5	9.5	65
JULY 3	116.0	12.7	115	32.7	3.7	35	25.6	3.7	25	35.5	5.3	30
	188.4	20.6	185	53.0	6	53	15.8	1.8	15	38.1	5.7	38
	96.4	11.5	90	75.0	9.3	70	18.8	2.5	19	16.9	2.2	16
JULY 7	57.5	16.8	55	100.1	28.8	100	21.0	4.5	19	10.8	2.3	10
	88.1	24.1	80	58.9	16.8	56	54.7	13.8	52	5.2	1.6	4.5
	79.1	21.8	75	49.7	14.2	48	40.1	9.4	40	31.9	7.0	31
JULY 13				175.6	45.3	160	63.7	14.2	60	49.6	10.7	47
				158.9	42.2	140	118.4	26.4	115	26.4	4.7	23
				108.2	27.9	100	94.0	20.4	85	34.3	7.5	32
JULY 22				89.1	22.9	80	113.4	23.3	105	8.7	2.0	8.8
				286.6	74.5	260	145.7	25.0	140	12.3	2.8	12
				186.9	48.6	175	46.0	9.8	43	13.5	3.2	12

APPENDIX i - cont'd.

DATE	WW	DW	VOL	WW	DW	VOL	WW	DW	VOL	WW	DW	VOL
JULY 26				43.4	9.0	41	119.0	16.9	115	12.2	2.5	11
				48.8	9.0	47	77.7	11.6	75	11.6	2.7	11
				44.1	8.1	42	66.5	10.9	65	13.7	2.6	14
AUG 2				16.0	3.5	16	17.6	3.0	17	3.0	0.6	2.6
				17.5	3.3	17	29.0	5.4	28	2.2	0.5	2
				8.4	1.7	8	15.3	2.8	15	4.4	1.0	4
AUG 10	26.8	5.3	27	14.3	4.6	14	23.2	6.2	22	2.6	0.8	3
	46.5	9.8	47	30.2	10.5	29	25.7	8.4	26	3.0	1.1	3
	50.6	10.2	51	36.9	11.8	35	23.3	7.0	23	1.5	0.6	2
AUG 24	37.8	4.3	40	109.4	26.8	100	75.1	16.8	70	0.8	.2	0.9
	66.2	12.6	63	113.0	26.9	98	62.2	14.6	58	0.9	.2	1.1
	66.0	12.0	60	57.9	16.1	51	53.0	13.4	48	2.9	.7	3.0
SEPT 15	116.6	27.0	105	18.1	4.5	18	27.3	6.0	25	5.0	1.4	5
	69.5	15.5	63	23.1	4.8	22	16.1	3.5	15	7.5	1.8	6
	102.5	25.5	95	22.9	4.8	21	27.7	6.5	25	9.0	2.2	8
SEPT 21	QUALITATIVE		SAMPLE	18.5	4.0	18	16.2	3.8	17	QUALITATIVE		SAMPLE
		ONLY		28.0	6.1	25	13.9	3.4	13		ONLY	
	69.3	19.7	60	16.8	3.9	16	16.5	3.8	16	16.8	4.9	16
OCT 13	QUALITATIVE		SAMPLE		INSUFFICIENT		FOR	SAMPLE				
		ONLY										
	57.8	16.8	55									

Appendix ii:

TABLE 1 — Average Biomass Per Month (g-Dry weight/m^2)

LAKE ONTARIO

Lake Ontario 1972

Owen	Bath	Emeric Pt.	Pt. Petre	Presqu'ile	Cobourg	Whitby	Oakville	Mean (g/m^2) All Locations
June '72	239.09 (123-313)	N.S.	115.72	N.S.	119.38	N.S.	N.S.	158.06
July '72	214.65 (121-393)	329.58 (188-719)	268.98 (158-802)	266.41 (42-1062)	211.40 (73-338)	164.37 (87-275)	96.92 (24-262)	224.33
Aug. '72	N.S.	27.91 (24-34)	50.31 (10-106)	140.31 (87-193)	51.58 (29-178)	N.S.	N.S.	67.52

Moore	Stoney Point	Nine Mile Point	Lakeside	Sterling	Sodus	Mean (g/m^2)
June 26-July 3	N.S.	120.66 (0-536)	169.66 (0-825)	60.5 (27-118)	N.S.	116.94
July 18-21	141.5 (33-217)	77.66 (3-339)	206.33 (38-368)	50.5 (0-104)	94.16 (9-291)	114.03
Aug. 18-22	82.5 (0-184)	2.16 (0- 7)	40.16 (8-102)	8.5 (0- 22)	3.66 (0- 10)	27.39

Sweeney	Stn. 207	Stn. 216	Stn. 222	Stn. 228	Stn. 237
July 27-Aug. 1	42.85 (0-128)	51.05 (0- 85)	106.17 (0-474)	59.76 (0-168)	41.5 (0-111)

APPENDIX iii

FILM RECORD OF CLADOPHORA SAMPLING. L. ONTARIO NEAR PARK ST. OAKVILLE SUMMER 1981

ROLL #1

1 -
2 - random shots taken of the bottom @ 5m depth
3 - showing extent of cover on 15/6/81
4 -
5 -
6 -
7 -
8 - as above but at 3m depth 15/6/81
9 -
10 -
11 -
12 -
13 - as above but at 1.5m depth 15/6/81
14 -
15 -
16 - diver + equipment (Ed Ingram).
17 -
18 - gravel beach west of sampling range
19 - " " " " " showing extent of wash up.
20 - landfill area below park near harbour 15/6/81

ROLL #2

1 -
2 - shoreline sampling sites 23/6/81
3 -
4 - random shots of bottom 23/6/81
5 - @ 1.5m
6 - bottom @1.5m showing production rate sample site 23/6
7 - swan - a pair of these make this stretch of shore home "
8 - slight wash up on shoreline "
9 - "
10 - heavy growth nr sheltered corner (see next slide) "
11 - sheltered corner harbouring heavy growth "
12 - "
13 - gravel beach showings loose clumps in water "
14 - and beginnings of wash up. "

Roll # 2 cont'd

15 - as. # 12-14 23/6
16 - harbour breakwater (outside) with patchy growth. 23/6
17 - extensive wash-up near sample sites 3/7
18 - " " along breakwater west of sites 3/7
19 - underwater view of floating mat 3/7
20 - gravel beach with heavy wash up 3/7

Roll # 3

1 -
2 - shoreline from west to east 8/7
3 - showing heavy washup.
4 -
5 -
6 - floating clumps. 8/7
7 -
8 - shoreline west to east with 8/7
9 - heavy washup
10 - bottom @ 5 m 8/7
11 - " " (white part of stake appear 1 foot long) 8/7
12 - bottom @ 5 m. 8/7
13 - floating mats from the water 8/7
14 - floating mats near sampling 8/7
15 - range
16 - floating mats from water @ 1m depth 8/7
17 -
18 - shoreline east to west showing 8/7
19 - patchy nature of wash up.
20 -

Roll # 4

1 -
2 - random pictures of bottom
3 - @ 3m depth 22/7/81
4 -

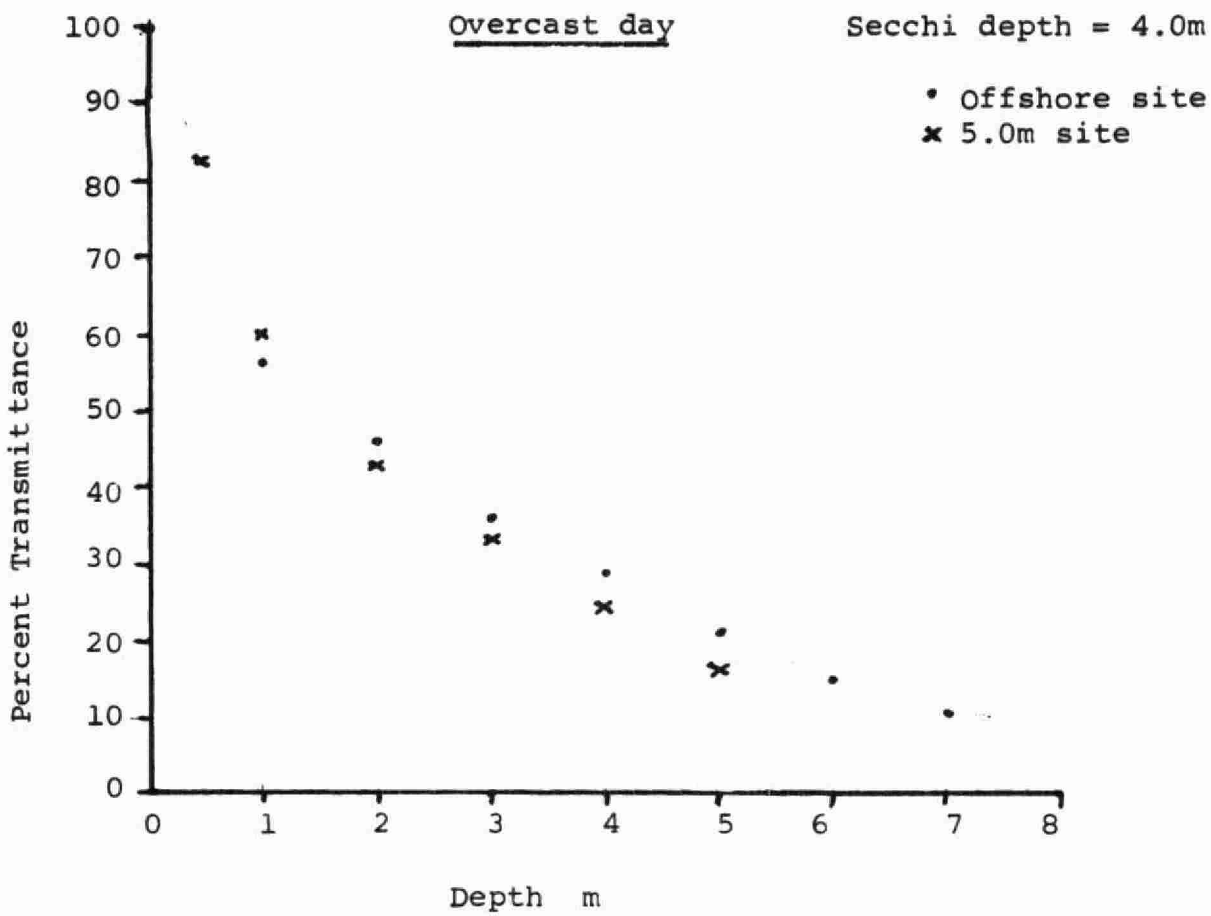
ROLL # 4 CONT'D

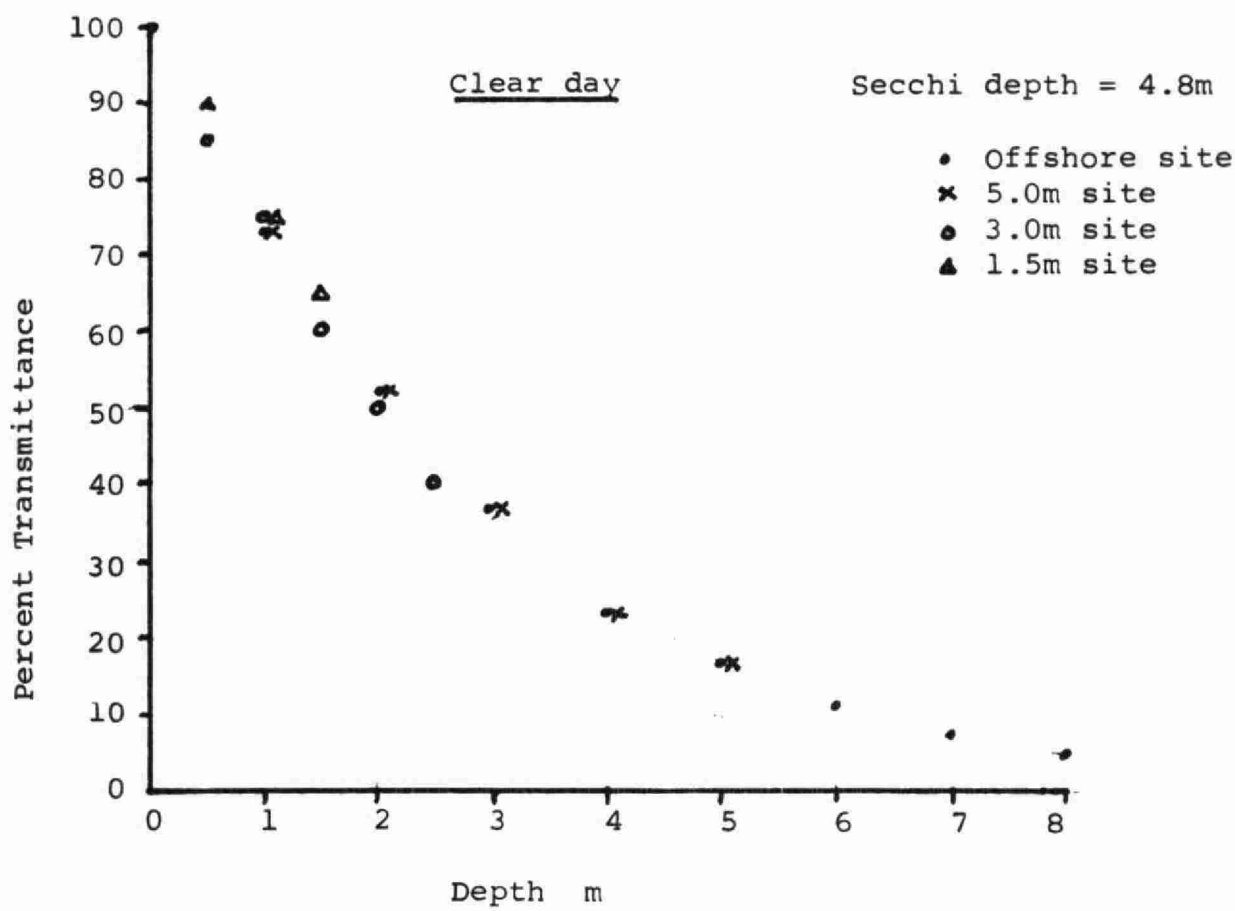
5 - horizontal shot just under surface near shore 22/7/81
6 - rotting mats pulled up from bottom near shore 22/7/81
7 - } horizontal shots just under surface
8 - } near sample range 22/7/81
9 - shoreline near sample range 22/7/81
10 - water surface ≈10m offshore - typical of whole area 22/7/81
11 - gardeners clearing the mess. 22/7
12 - gravel beach - mats have settled below surface but still visible 22/7
13 - horizontal shot just under surface - off gravel beach. 22/7
14 - } loose algae just under
15 - } the surface. 22/7
16 - ~~birds on algal~~ rotting mat not yet broken up 22/7
17 - } birds ~~mats~~ on 26/7
18 - } algal mats
19 - gravel beach - clear of algae 26/7
20 - gravel beach below park with heavy wash up 26/7

ROLL # 5

1 - }
2 - } Bottom @ 5m showing sites cleared 2/8/81
3 - } for slutting rate samples
4 - }
5 - } Bottom @ 3m. 2/8/81
6 - }
7 - } Bottom @ 1.5m 2/8/81
8 - }
9 - } shoreline at sampling range showing
10 - } fringe growth 10/8/81
11 - gravel beach clear of algae 15/9/81
12 - shoreline near sample range 15/9/81
13 -
14 -
15 -
16 -
17 -
18 -
19 -
20 -

Appendix iv Light Transmittance versus Depth





	DATE DUE		